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Federal Aviation Administration

Advisory Circular

Subject: AIRPORT FIRE AND RESCUE PERSONNEL PROTECTIVE CLOTHING

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1. PURPOSE. This advisory circular (AC) was developed to assist airport management in the development of local procurement specifications for an acceptable, cost-effective proximity suit for use in aircraft rescue and firefighting operations.

2. APPLICATION. The standards contained herein are recommended by the Federal Aviation Administration for applications on all airports as appropriate. They are mandatory for Federally funded projects and are an acceptable means for compliance with Federal Aviation Regulation Part 139 as it pertains to the protective clothing requirements for airport firefighting and rescue personnel.

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CHAPTER 1. INTRODUCTION

1. SCOPE. This advisory circular (AC) identifies operational characteristics of a proximity suit for aircraft rescue and firefighting operations.

2. GENERAL.

a. Proximity suits are designed for high conductive and radiant thermal energy conditions. They usually consist of an aluminized outer shell with an inner layer of thermal protection which should allow a firefighter to operate effectively for moderate periods of time, at least five minutes, in ambient temperatures above 500°C. (932°F.) and radiant conditions up to 1.2 cal/cm^2-sec. The proximity suit ensemble should withstand occasional short-duration flame contact but is not designed for fire entry. The components which make up a complete ensemble include coat and trousers, gloves, boots (with or without aluminized outer protection), hood, helmet and reflective visor. Proximity suits are primarily used in situations involving burning flamable or combustible liquid fuel where radiant thermal energy levels are quite high relative to structural firefighting conditions. The proximity suit is not intended or adequate for fire entry or for extended service in the structural firefighting environment.

b. Proximity suits must provide the mobility, durability, and thermal protection performance capabilities necessary to allow aircraft firefighting and rescue personnel to perform efficiently under extreme environmental conditions of intense radiant heat as well as high and low ambient temperatures. The components which constitute a complete proximity suit are coat, trousers, hood (including helmet and visor), gloves and boots. The ensemble should be compatible with a self-contained breathing apparatus (SCBA) and a communications system.

c. These standards may be exceeded to include additional proximity suit capabilities and accessories. However, the primary function of the suit described by these standards is to provide thermally resistant, maneuverable, and cost-effective protective clothing for aircraft rescue and firefighting personnel. The purchaser should exercise caution in the specification of "nice-to-have" garment options so as not to degrade the level of thermal protection, maneuverability, durability, and fit, or reduce the ensemble's cost-effectiveness.

3. RELATED CLOTHING.

a. Turnout Gear and Bunker Suits. Turnout gear and bunker suits are worn for structural firefighting. The ensemble normally includes coat, trousers, boots, gloves, helmet and clear visor. The protective layers normally include a nonreflective outer shell, vapor barrier, and thermal liner. The garment system is normally compatible with a self-contained breathing apparatus (SCBA). These suits are not intended for flame contact or intense conductive and radiant thermal energy. The upper limits of thermal energy conditions ordinarily faced by structural firefighters are 300°C. (572°F.) and 0.3 cal/cm^2-sec. A reflective outer shell is not commonly used because the radiant energy levels are not high enough to warrant it and the wear characteristics of an aluminized outer shell cannot withstand the high levels of abrasion normally experienced in structural firefighting. Airport operators often supplement their proximity suits with these ensembles to reduce operational costs when their firefighters also perform structual firefighting duties.

b. Approach Suits. Approach suits are primarily designed to allow a firefighter to come within close proximity of high conductive and radiant thermal energy for a short period of time. They usually include a hood with helmet and visor, coat and trousers (usually one-piece), aluminized foot protection and gloves. Approach suits do not normally include thermal liners but can be designed to be worn over structural firefighting protective gear including a pouch for covering a SCBA air tank. Approach suits are not designed to withstand high thermal conditions, flame contact, or long periods of time in close proximity to a fire.

c. Entry Gear. This equipment, sometimes referred to as a fire entry suit, is designed for moderate duration fire entry. These suits are very heavy and cumbersome, and two people are needed when suiting up. Once suited, maneuverability is severely limited. These characteristics make entry gear impractical for airport fire and rescue operations. It is not an acceptable substitute for the proximity suit. Entry gear components include full head, hand, foot, torso and limb protection including helmet, hood and reflective visor. The SCBA is enclosed by the suit.

4. BACKGROUND.

a. Fire Environment. Aviation fuel fires present the firefighter an environment with temperatures ranging upwards from 300°C. (572°F.) and radiation levels ranging from 0.5 cal/cm^2-sec to 2.7 cal/cm^2-sec. In structural firefighting, these levels would be considered emergency conditions, and the protective clothing normally used by that service would only allow the structural firefighter 15 or 20 seconds to escape. Proximity suits, with an aluminized outer shell and insulating inner layers, are designed to allow a firefighter to operate under these severe conditions for useful periods of time.

b. Reflective vs. Nonreflective Outer Shell.

(1) General. The advent of advanced primary firefighting agents, such as Aqueous Film Forming Foam (AFFF), in combination with powerful agent pumps and long-range turrets now enable airport firefighters to control and essentially extinguish large aviation fuel fires while still in the attacking vehicle. This means that aviation fuel fires can often be controlled in minutes without the use of hand lines. Therefore, firefighters often do not need to leave the rescue vehicle before the levels of heat and radiation are low enough to allow the use of nonreflective gear. Consequently, a small number of airport fire services are moving towards the use of nonreflective protective clothing. Moreover, the use of reflective gear for rescue operations is questioned on the basis that, if the fire environment is severe enough to require reflective gear, there would be no potential for survivors. This does not, however, take into account case histories where passengers have been alive inside an aircraft with a fire on the outside requiring an aggressive attack.

(2) Comparison of Surface Temperatures When Exposed to Radiant Energy. A structural fire exposes firefighters to radiant energy levels of 0.6 cal/cm^2-sec, 90 percent of the time. This energy level is sufficient to generate a clothing surface temperature of 400°C. (752°F.) to 500°C. (932°F.) with nonreflective materials and only 100°C. (212°F.) to 250°C. (482°F.) when reflective materials are used. For comparison see Figure 1.

(a) At 0.6 cal/cm^2-sec. A non-reflective clothing thickness of 1 cm with a surface temperature of 400°C. (752°F.) would allow approximately twenty seconds before the pain threshold of the skin is reached and one minute until the skin blisters. The same energy load on reflective clothing of the same 1 cm thickness would generate a surface temperature of 200°C. (392°F.). These conditions would allow approximately fifty seconds before the pain threshold is reached and two minutes until the skin blisters. Thus, it is clear that at the same thermal load, reflective clothing provides twice the operational time of nonreflective clothing.

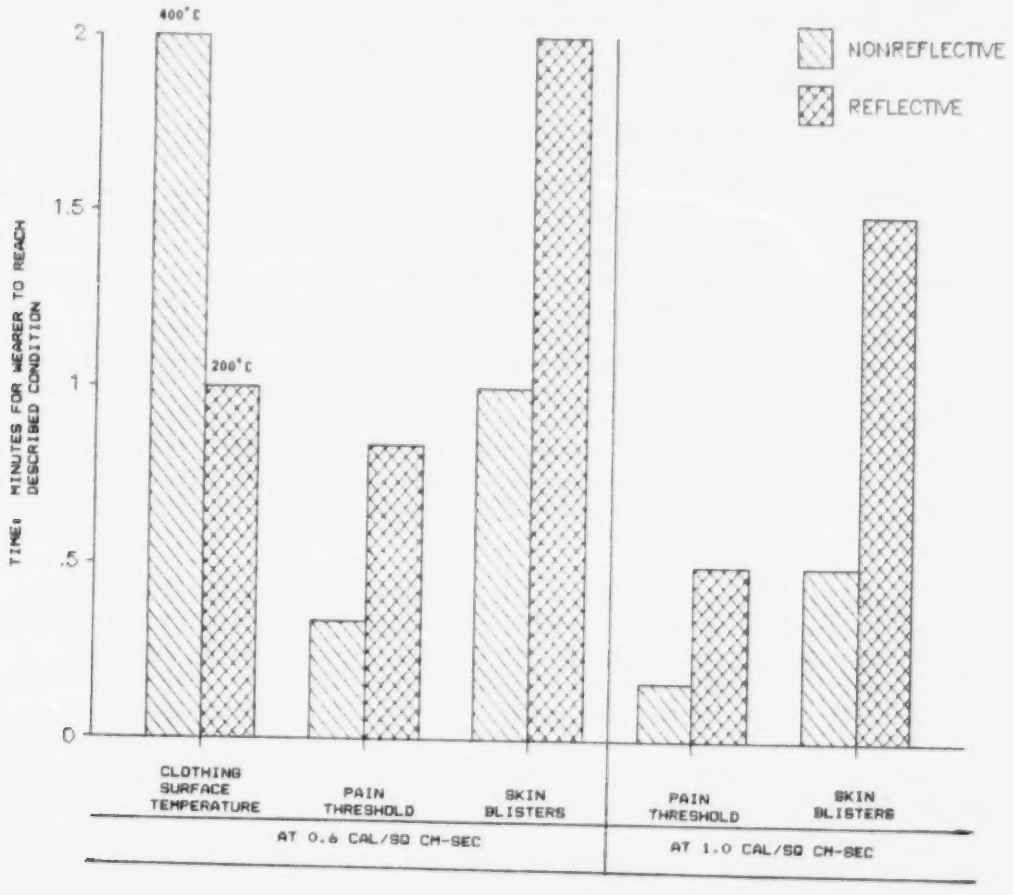

Figure 1. Nonreflective vs. Reflective Clothing (not to scale).

(b) At 1.0 cal/cm^2-sec. Also shown in Figure 1, at a higher radiant energy level and the same clothing thickness, the time to pain for reflective clothing is 30 seconds but only 10 seconds for nonreflective clothing. The time to blister for reflective clothing is one and one-half minutes, while for nonreflective clothing, it is only 30 seconds. This clearly shows that at the higher radiant energy level of 1.0 cal/cm^2-sec, reflective clothing offers protection for approximately three times as long as the nonreflective clothing.

As the radiant energy level impacting on the surface of the clothing rises, the temperature of the outer surface rises, and the energy flowing through the protective clothing rises even faster. Thus, as the incident radiation levels encountered rise above 1.0 cal/cm^2-sec, a reflective surface plays an increasingly crucial role in keeping the clothing surface temperatures at tolerable levels. The increased weight of the aluminized surface is less than 10 percent of clothing weight while the protection offered under severe fire conditions is at least doubled. In conclusion, reflective clothing should be provided "first due" aircraft rescue and firefighting personnel, with the possible exception of the vehicle driver. Other supporting personnel should be provided protective clothing appropriate to their operational task and the associated hazard.

c. Thermal Resistance, Maneuverability and Cost-Effectiveness.

(1) Acceptable Compromise. The objective of any proximity suit specification is to provide an ensemble that has maximum thermal resistance; is highly maneuverable and is affordable. Unfortunately, these are mutually exclusive end products. Hence, an acceptable compromise must be achieved during the specification writing process. Furthermore, there are several factors relating to the selection of materials and the construction methods required to assemble the protective garment which play competing roles in any effort to obtain high thermal resistance and maneuverability in a cost-effective ensemble. By "cost-effective," we mean an ensemble that has an acceptable level of thermal resistance (not necessarially the maximum that technology can provide); is sufficiently maneuverable to allow the wearer to perform the required work rapidly and for a useful period of time; and is durable enough to provide a safe service life of 3 to 5 years.

(2) Competing Factors. There are a number of factors involved in materials selection and construction which play important roles in determining thermal resistance, maneuverability and durability, all of which impact cost-effectiveness. The key factors include fabric thickness, density or entrapped air, air permability or porosity, the number of layers, compression and moisture resistance. Figure 2 highlights the competing nature of these factors and their interrelationships with thermal resistance and maneuverability. Figure 3 graphically displays the same information in more detail.

(a) Thickness. In general, thermal resistance, is directly proportional to thickness but as the clothing becomes thicker and heavier, compression causes the rate of return to diminish.

(b) Density. As the density decreases (i.e. as the number of small air gaps within the fabric increases), the insulative value goes up. This relationship continues until density decreases to 0.06 g/cm^3 where convective currents

become significant and begin to reduce thermal resistance. The fabric densities of fire protective clothing should be greater than 0.06 g/cm^3.

(c) Air Permeability. Air permeability is a measure of the fabric's resistance to air penetration, which can include hot air. As air permeability decreases, thermal resistance increases. This factor should only be considered after thickness and density when comparing fabrics of various weaves and materials.

(d) Layers. Thermal protection is improved by the insulation value offered by the air trapped between the layers. In general, the greater the number of layers, the higher the level of thermal protection offered. However, this benefit diminishes when the bulk of layering impacts maneuverability.

(e) Compression. When compression is increased, thermal resistance is reduced. This correlates with an increase in material density and a decrease in layer effectiveness and fabric thickness. Therefore, at compression points e.g., knees and elbows, an additional layer of thermal protection is recommended.

(f) Moisture. Increasing moisture in a fabric reduces its thermal resistance. Moisture transmits more heat than the air it displaces.

When	Thickness	Density	Air Permeability	Layers	Compression	Moisture
Is	UP	DOWN	DOWN	UP	UP	UP
Thermal Resistance Is	UP	UP	UP	UP	DOWN	DOWN
And Maneuverability Is	DOWN	UP	DOWN	DOWN	UP	DOWN

Figure 2. Major Factors in Thermal Protection.

(3) Future Improvements.

(a) Reflective Trim. Although referred to as "reflective trim," this
n is generally less reflective than aluminized outer shell material. High
perature exposure can lead to burns underneath these less reflective portions of
suit. While reflective trim on proximity suits is not recommended, reflective
on the lower portions of the back of the hood drape, which do not contact the
surface and do not normally face the radiant energy source, may be specified.

(b) Take-up Straps on Sleeve. Take-up straps around the wrist area of
sleeve, while used in the past, are generally not cost-effective. The newer
let designs have eliminated the need for tightening straps in the wrist area.

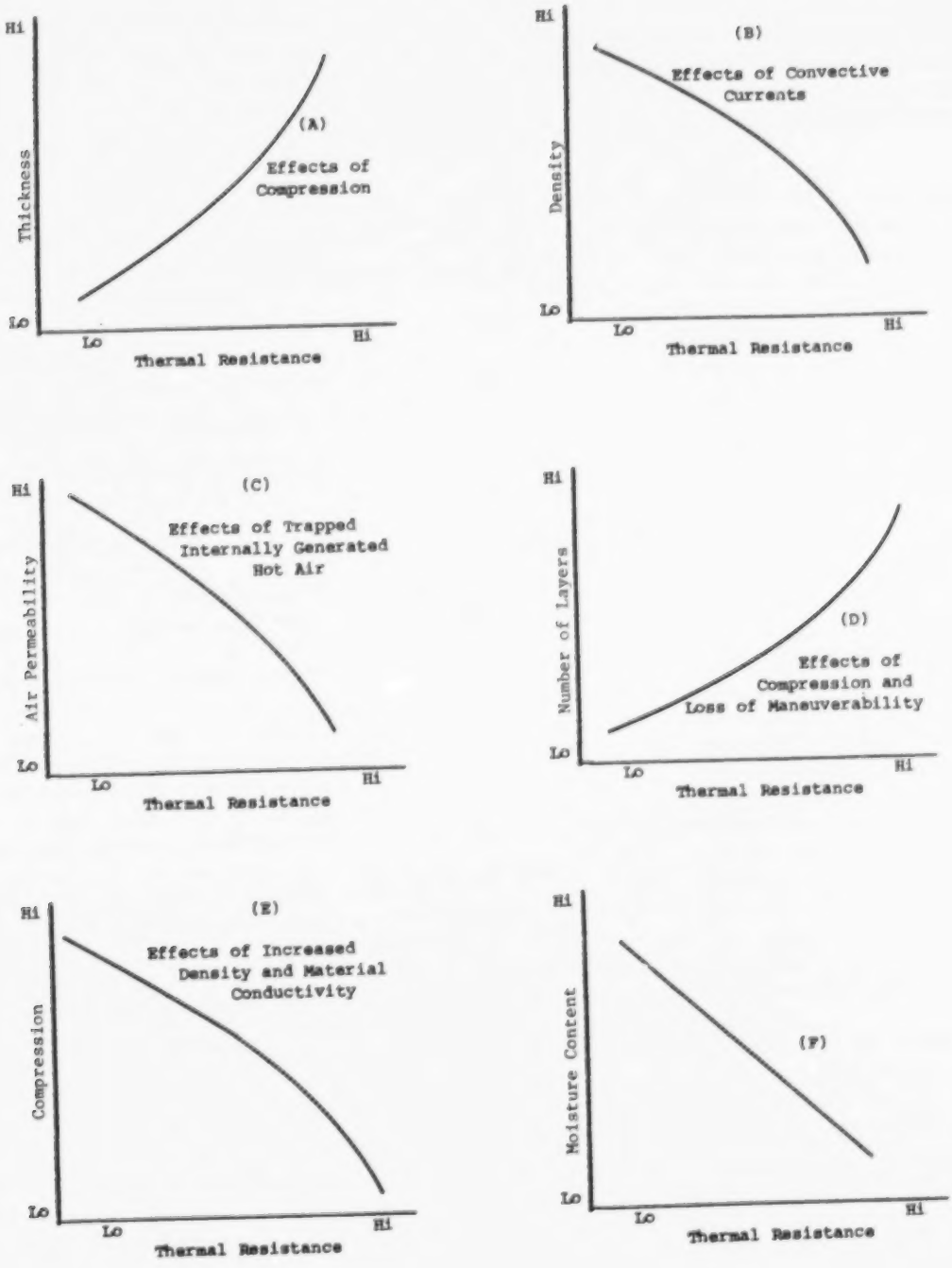

Figure 3. Interaction of Factors Affecting Thermal Resistance.

CHAPTER 2. TORSO AND LIMB PROTECTION

SECTION 1. GENERAL CHARACTERISTICS OF PROXIMITY SUIT COAT AND TROUSERS

5. REQUIREMENTS. The proximity suit coat and trousers combination must enable firefighters to perform their work safely. To protect a firefighter against burns, the proximity suit coat and trousers must be capable of keeping the skin temperature below about 45°C. (113°F.) for a minimum of five minutes in ambient temperatures up to 500°C. (932°F.) as well as of protecting against radiant energy up to 1.2 cal/cm ^{2}-sec. It needs to be capable of protecting for a short duration emergency egress (ten to fifteen seconds) in ambient temperatures up to 1000°C. (1832°F.) and radiant energy up to 2.5 cal/cm^2-sec. The ensemble must be able to withstand occasional licks of flames in addition to keeping the wearer protected from water, steam and other firefighting agents. In addition to the thermal protection requirements, the garment should impose as little impediment to wearer maneuverability as possible. Finally, the proximity suit coat and trousers should be durable to minimize the replacement rate; allowing the life-cycle cost to offset initial cost.

6. RELATED FACTORS. Factors influencing the choice of ensembles, particulaly coat, trousers, and gloves are:

a. Fabric. The firefighter's protective ensemble should be made up of multiple layers of a carefully selected combination of water, fire, and heat resistant fabric materials.

b. Maneuverability. Both the coat and trousers should allow the firefighter to operate effectively with as little effort as possible. Important movements include bending and twisting at the waist, lifting the arms above the head, and bending the elbows and knees. The factors affecting these movements include fabric bulk, weight and flexibility, number of layers, functional design, style, and fit.

c. Purchase Price. The major factors affecting the purchase price are the fabrics selected, the fabrication complexity, the amount of testing required if any, the complexity imposed by the style and any compatibilities required (e.g. with SCBA), the manufacturer, the options exercised and the quantity of items ordered.

d. Durability. The durability of garments determines how often they have to be replaced. While perhaps imposing a higher initial purchase price, a durable garment is extremely cost-effective when life-cycle costs are considered. The factors affecting durability include the choice of fabrics, especially for the outer shell, and the construction details.

e. Maintainability/Repairability. Simple maintenance and repair procedures have a major beneficial impact on life-cycle costs, as well as on user satisfaction and appearance. See paragraph 16 for a more detailed discussion.

7. STYLES. The style options considered include: the conventional 35- to 40-inch coat and waist-high trousers; the short (less than 30-inch) coat with bib-style trousers; and the one-piece coverall style.

a. One-Piece Coverall. Also known as a jumpsuit, this is not a recommended style for use at airports for the following, real or perceived, limitations in functionality:

(1) Donning. It reportedly takes longer to put on a one-piece proximity suit than the other available configurations, thus delaying crew response. This is a major deficiency in airport firefighting applications.

(2) Maneuverability. A one-piece proximity suit reportedly limits the wearer's maneuverability when bending forward from the waist, especially when bending the knees. This causes firefighters to lose balance and fall forward. If not individually sized, the crotch of a one-piece proximity suit is usually quite low. This hinders the wearer's maneuverability on steps and ladders.

(3) Ventilation. The front of a one-piece proximity suit does not allow as rapid ventilation, when opened as the other available configurations.

b. Long, 35- to 40-Inch Coat with Waist-High Trousers. This style option is widely used and accepted.

(1) Maneuverability. Maneuverability is somewhat limited due to the length of the coat, which hampers bending from the waist.

(2) Ventilation. This style affords greater ventilation than either the short coat with bib-style trousers or the one-piece coverall. Ventilation is maximized when the coat is opened or removed during breaks because, unlike the other two configurations, the torso is not covered.

c. Short Coat and Bib-Style Trousers. This style combines a shorter, less than 30-inch coat with higher, bib-style trousers.

(1) Maneuverability. Maneuverability is apparently greater with this style than with the long style coat and trousers since there is less binding in the waist area. In addition, the coat is lighter and is thus less restrictive to arm movements.

(2) Ventilation. Ventilation with the short coat and bib-style trousers configuration is greater than with the one-piece coverall but, due to the higher bib-style trousers, not as great as with the long coat and trousers configuration.

SECTION 2. SELECTION OF COMPONENTS

8. OUTER SHELL.

a. General. As the first layer of protection, the outer shell must allow the firefighter to perform a wide variety of tasks under the severe thermal environmental conditions discussed in paragraph 4. The outer shell should also withstand the various liquids and foams found in the aircraft firefighting environment and have low levels of penetration and absorption. Absorption of liquids increases the thermal capacity of the suit which could slow the temperature rise of the garment. However, it also increases garment weight, heat transmittance, and raises the possibility of post-fire burns due to heat stored in the surface of the garment. The outer shell fabric may be either woven or knit. A woven fabric provides better strength and durability, while a knit provides better thermal insulation and can be less stiff thus allowing better mobility.

b. Functional Characteristics. The desirable functional characteristics include:

(1) Durability. The outer shell should be resistant to repeated abrasion, resist tearing and puncture, and resist charring or melting.

(2) Flexibility. The outer shell should be flexible to allow easy movement by the firefighter.

(3) Weight. The outer shell should be low in weight to reduce, as much as possible, the burden of the firefighter.

(4) Maintainability. The outer shell should be easy to clean and repair if necessary.

c. Candidate Materials.

(1) Nomex®. Nomex® is used commonly as a base fiber in the outer shell. It exhibits rather good functional characteristics.

(a) Thermal and Burn Characteristics. Nomex® will not support combustion and is self-extinguishing if a flame is applied. It will consistently pass standards of maximum two seconds after-flame, two seconds afterglow, and four inches char length per Federal Test Method CS191:5903. However, Nomex® will melt and begin to degrade at temperatures above 370°C. (698°F.).

(b) Puncture, Breaking Strength, and Durability. Nomex® is quite durable and exhibits high abrasion resistance and tear strength.

(2) Kevlar®. Although presently not used as commonly as Nomex®, perhaps because it is newer, and somewhat more expensive, Kevlar® exhibits greater capabilities in thermal resistance, puncture and breaking strength, and durability, but it is a stiffer material than Nomex®. The main type of Nomex® available, Nomex III®, uses five percent Kevlar® in its weave to increase its puncture and breaking

strength while not greatly increasing the price. Various textiles are often used in combination with Kevlar® to attain desired characteristics; a 40/60 weave of Kevlar® and polybenzimidazole (PBI) is not uncommon.

(a) Thermal and Burn Characteristics. Kevlar® exhibits little or no shrinkage at high temperatures but decomposes at temperatures above 500°C. (932°F.). It will not support combustion and passes the standards of maximum two seconds after-flame, two seconds afterglow, and four inches char length per Federal Test Method CS191:5903.

(b) Puncture, Breaking Strength, and Durability. A unique property of Kevlar® is its superior puncture and cutting resistance and very high abrasion resistance. These inherent properties provide a strong and long-wearing protective envelope.

(c) Flexibility and Extensibility. Kevlar® does not exhibit high flexibility due to its low extensibility and high modulus; only three to four percent elongation is tolerated before it breaks, which is less than Nomex®.

(d) Cost. Kevlar® is slightly higher in cost than Nomex®.

(3) Polybenzimidazole (PBI). Although less widely used in proximity suits than other protective fibers, PBI exhibits superior characteristics in all protective criteria relative to Nomex® but is generally priced higher than both Nomex® and Kevlar®.

(a) Thermal and Burn Characteristics. PBI exhibits superior thermal characteristics to both Kevlar® and Nomex®, degrading at temperatures above 560°C. (1040°F.). Its shrinkage at high temperatures is less than that of Nomex®, and PBI will not burn in air. Regarding Federal Test Standard CS191:5903, PBI exhibits no after-flame, a one second afterglow and less than one-inch char length, surpassing both Kevlar® and Nomex®.

(b) Puncture, Breaking Strength, and Durability. PBI exhibits a slightly lower breaking and tear strength than Nomex®, and its abrasion resistance in cycles-until-destruction is 20 percent less using the Emery Abradant Method, No. 5308.1. Although PBI is a stronger material and probably has greater puncture resistance, it may be less durable in operationel service than Nomex®.

(c) Flexibility and Extensibility. PBI has a smaller percentage elongation at breaking than Nomex®, but larger than that of Kevlar®. This may indicate that PBI has greater flexibility than Kevlar®, but less than that of Nomex®.

(d) Cost. PBI is more expensive than Nomex® and Kevlar®. However, material fabricated with a blend of PBI and Nomex® or Kevlar® might not be significantly higher in cost than Nomex® or Kevlar® alone if there were a volume demand.

(4) Rayon. If used as the base material for the outer shell, rayon should be a permanently flame retardant (PFR) rayon to ensure the desired flame

resistant characteristics. The use of PFR rayon for proximity suits does not appear to be common. Weights of rayon higher than 15 ounces per square yard may be required to provide the necessary protection. That fabric weight, however, results in restricted mobility.

(5) Kynol®. Kynol® exhibits good flame and thermal resistance characteristics and has good flexibility. However, it appears to have a relatively low breaking strength indicating low durability; making Kynol® unsuitable for an outer shell material.

(6) Durette®. Durette®, a material similar to Nomex®, exhibits better performance characteristics than Nomex® but is not yet produced in sufficient quantities to make it price competitive. Although Durette® has not been used in proximity suits, it may be available in the future.

(7) Glass and Asbestos. Both of these fibers are available at a low cost and exhibit very favorable characteristics when subjected to intense heat. These characteristics include high strength, resistance to heat, and nonflammability. However, the poor characteristics of these fibers, including low flexibility, high weight, and low resistance to abrasion, coupled with the known health hazards of asbestos fibers, make them both unsuitable.

9. VAPOR BARRIER.

a. General. The vapor barrier is required to prevent externally generated liquids and gasses from penetrating the garment and must withstand the high temperatures conducted through the outer shell, while allowing for the maximum maneuverability of the firefighter.

b. Functional Characteristics. The desirable functional charateristics include:

(1) Water Resistance and Absorption. The vapor barrier should have a high level of water resistance and a low level of water absorption. If liquids penetrate the vapor barrier, the thermal liner and any garments worn beneath the thermal liner can be saturated causing an increase in suit weight, thermal transmission, and the possibility of contact burns as well as scalding. Leakage at the seams of vapor barriers can be a problem. Therefore, sealing of the seams should be clearly specified.

(2) High Temperature. The vapor barrier should withstand high temperatures. Despite the insulation afforded by the outer shell, temperatures reaching the vapor barrier can exceed 300°C. (572°F.) as a result of the high ambient temperature plus the temperature rise induced by radiant energy at the outer shell.

(3) Flexibility and Weight. The vapor barrier should be flexible to allow the firefighter maximum maneuverability. The weight and bulk of the vapor barrier should be minimal to give the firefighter as small a burden as possible.

c. Candidate Materials. Two materials have been identified which are appropriate for use as the vapor barrier.

(1) Neoprene. Neoprene is the most common and lower cost option. It is used as a coating which must be applied to a substrate. As a vapor barrier, neoprene does not allow penetration of either water droplets or water vapor.

(2) Gore-Tex®. Although more expensive than neoprene, Gore-Tex® film exhibits greater vapor transmission capabilities. Gore-Tex® film is bonded to a substrate to help protect it from abrasion and dirt which can degrade its capabilities. Gore-Tex II®, which is now available, has an added polyurethane coating to prevent "sweat degradation" of its vapor barrier properties. Gore-Tex®, if properly protected, allows some penetration of water vapor but not water droplets. Thus, Gore-Tex® is both "breathable" and waterproof: liquids cannot penetrate but perspiration and air can. This suggests that steam would also be able to penetrate Gore-Tex®. This vapor permeability may reduce the possibility of heat exhaustion caused by the trapping and build-up of metabolic heat and may be preferred in warm climates. But the impermeable nature of many of the aluminized shell materials may negate any benefit of a vapor permeable "vapor barrier" layer.

10. THERMAL LINER.

a. General. The thermal liner serves as a buffer between the skin of the firefighter and the high temperatures reached at the outer layers of the proximity suit. In addition, the thermal liner should absorb and dissipate perspiration and allow for the maximum possible maneuverability of the firefighter.

b. Functional Characteristics. The desirable functional characteristics include:

(1) Insulation. The thermal liner should insulate the firefighter from the high temperatures penetrating the outer shell and vapor barrier of the proximity suit. It is generally thought that the insulative value of a fabric is determined by its thickness and density and is virtually independent of the fabric type, provided the fabric structure remains intact. Since the air trapped between the fabric layers generally provides more insulation than the fabric layers themselves, the thermal contribution of any fiber is much less meaningful with respect to insulation than the ensemble design.

(2) Weight and Bulk. These characteristics of the thermal liner should be as low as practical to allow the greatest mobility while still preventing skin contact with the outer layers of the garment.

(3) Flexibility and Durability. The thermal liner should be flexible, to optimize mobility and durable to withstand the wear of frequent donning.

(4) Absorption and Evaporation of Liquids. Although the absorption of externally generated liquids is undesirable, the thermal liner must absorb and dissipate internally generated liquids. During firefighting, the body generates 300 to 400 watts or more of metabolic heat. This, in addition to any heat penetrating

the thermal liner would, under normal conditions, eventually be dissipated by the evaporation of perspiration on the skin. Any perspiration that does not evaporate does not provide cooling and, therefore, increases the discomfort of the firefighter. A skin relative humidity above 50 percent at normal skin temperature is not only an uncomfortable level, but one which has been associated with decrements in performance and judgment, thus, increasing the risk of accidents, and can eventually cause heat exhaustion. To absorb perspiration, the innermost layer of the thermal liner should be a fabric with a relatively high moisture-regain level. If the absorbed perspiration can be evaporated, the risk of heat exhaustion is reduced. To evaporate perspiration, airflow is needed between the layers of the suit. The use of a multiple-layer thermal liner will increase the number of air layers and, depending on design, may increase the ventilation and accelerate the evaporation. However, a balanced design is required because the use of multiple layers will also increase the thermal insulation of the suit due to the greater number of entrapped air layers. This, in turn, will decrease the potential for evaporative cooling.

(5) Weave. There are many ways to construct fabrics from the available materials. Depending on the specific weave used, materials will exhibit many different characteristics. Weave determines density, flexibility, thickness, strength, and durability; all of which affect the performance characteristics of the fabric. Weaves with high insulative capabilities may not have good durability characteristics and may need a facing material quilted to the fabric to ensure durability through structural integrity.

c. Candidate Materials. PFR cotton, wool, Kevlar® and Nomex® are the most commonly used fibers in materials for thermal liners.

(1) PFR Cotton and Wool. These are good candidates because of their high potential for water permeability; a characteristics which allows greater comfort over a longer work time due to evaporation of perspiration. This in turn slows the rise in body temperature associated with physical exertion in high temperature environments. Wool has excellent thermal insulation properties and is more flame-resistant than FR rayon. It also has a higher level of moisture regain than Kevlar® and Nomex®. PFR cotton and wool are also lower in cost than Kevlar® and Nomex®.

(2) Kevlar® and Nomex®. These fabrics have the best wear characteristics. However, they have relatively low levels of moisture-regain and water permability; properties which limit the evaporation of moisture important to natural body cooling. They are also more expensive than PFR cotton, wool, and FR rayon as well as glass fabrics. However, in spite of the cost disadvantages Nomex® is the recommended material.

(3) Glass and PFR Rayon. Although these fabrics are relatively inexpensive, they both have significant operational disadvantages. Most glass fabrics are, (due to their density) high in weight relative to the level of insulation provided, hence, they are not recommended. Although FR rayon has good insulative properties relative to its weight, it is not recommended due to its relatively low burning point and it is not as durable as Kevlar® and Nomex®.

d. Attachment to the Outer Shell. The thermal liner is often detachable from the outer shell for ease of laundering. However, even in warm climates, firefighters should not wear proximity suits without the thermal liner. Although some garments have "winter liners" which are removable for the hotter seasons, outer shells are not designed to operate without an inner liner. The absence of an insulative layer under the outer shell will limit the firefighter's capabilities and may result in serious injury. Hence, permanent attachment of the thermal liner to the outer shell is advised.

(1) Sewn. The thermal liner can be permanently sewn to the outer shell of a garment. However, this limits the ventilation between layers, adds manufacturing complexity, and can reduce function and decrease durability. To encourage ventilation between layers and still insure that the thermal liner cannot be removed, the liner can be permanently sewn in only at the neck of the coat and along the waist or bib area of the pants. Snaps or other attaching tabs can be used along the front closure, bottom edge and sleeve cuff of the coat and along the pants cuff.

(2) Snaps. Snaps are commonly used to attach the thermal liner to the outer shell, allowing removal of the liner for laundering. However, this also permits the thermal liner to be left out of the garment which reduces its safety.

(3) Velcro®. The use of Velcro® tabs as the sole fastener ensures tight attachment of the thermal liner to the outer shell while allowing removal of the liner for laundering. Again, the use of Velcro® also permits the thermal liner to be left out of the garment. Velcro® is often used along the neck and front closure of the coat with the bottom edge left open or snapped to ensure ventilation. One-half inch wide Velcro® is recommended. It should withstand high and low temperatures, hold under wet conditions and withstand laundering. The durability of Velcro® limits garment life and may require replacement to extend garment life.

11. STITCHING AND SEAMS.

a. Functional Characteristics. Seams should be double-stitched. All points of stress should be bar-tacked. The load-bearing seams should have a breaking strength of eighty pounds or 80 percent of the fabric breaking strength; whichever is highest.

b. Candidate Materials. The thread used for all seams, pockets, and fastners should be able to withstand stresses under high temperatures. The thread should be Nomex®, Kevlar® or an equivalent.

12. POCKETS.

a. General. Pockets are used on proximity suits to hold gloves, small hand tools, spanners, flashlights, radios, hose belts and other items. The style, location and size of each pocket are determined by its expected use and the coat and trousers style.

b. The Functional Characteristics. The two general-use pockets found on most proximity suits are addressed here.

(1) Flat. The flat or patch-style pocket is common and inexpensive. The design is a flat piece of material sewn to the outer shell of the coat or trousers. This style is safe because the pocket lies flat on the garment surface and thus does not catch on equipment or obstruct the movements of the firefighter. However, because of its low volume capacity and constricted opening, it may be difficult to use this type of pocket while wearing gloves.

(2) Box. These pockets resemble boxes in design and have greater volume, are more accessible and more expensive than the patch-style pockets. A significant drawback is its high profile which increases the possibility of catching on equipment and obstructing the movements of the wearer. This style of pocket is not recommended.

(3) Bellows. Although not commonly available on the basic garment, this style is a frequently requested option. The bellows design incorporates naturally contracting-expanding accordion-like sides which, unlike the box-style, allow the pocket to lie flat when not in use, and expand as necessary to provide needed box-style volume. This style is more expensive and more utilitarian than the patch style. It is about the same cost and safer than the box style. Hence, it is a recommended, cost-effective option.

(4) Size. General use pockets range in size from nine to twelve inches in height and ten to twelve inches in width. Bellows and box-style pockets are usually one and one-half inches deep.

(5) Drain Holes. Drain holes should be specified for all pockets. The designs available include eyelets and pockets with specially sewn corners which allow liquids to drain out. When eyelets are chosen, brass should be specified because of its low corrosion properties. There should be two or three eyelets on each pocket.

(6) Flaps. Pocket flaps minimize the amount of debris and water entering the pockets. Pocket flaps and the preferred design should be specified when ordering proximity suits.

(a) Wider than Pocket. This is a common flap design and ensures ample coverage of the pocket.

(b) Same Width as Pocket. This design enables the wearer to have the flap either cover the pocket opening or tuck inside the pocket.

(c) Fasteners. Flap fasteners secure the flap over the pocket to limit the amount of water and debris entering the pocket. When used with a bellows-style pocket, the fastening of the flap compresses the pocket thus lowering its profile and increasing the wearer's maneuverability. Snaps are common and inexpensive flap fasteners, although they may be difficult to fasten with gloved hands. Although more expensive than snaps, Velcro® allows flexibility in adjusting the tightness of the flap which can help lower the profile of box and bellows-style pockets. Velcro® is also easily fastened with gloved hands.

(7) Coat. Pockets are recommended on the long coat but are not recommended on the short-style coat because of the difficulty in reaching the pockets high on the torso.

(8) Trousers. Pockets are used on the high bib-style trousers but generally not recommended on the conventional waist-high trousers/long coat ensemble.

(9) Location. The two general-use coat pockets should be located just forward of the side of the coat with the bottom edge of the pocket within a few inches of the bottom edge of the coat. The two general-use trouser pockets should be located on the sides of the bib-style trousers with the openings just below the bottom edge of the coat. Compatibility of the pocket locations with the straps used to secure the SCBA to the firefighter's back should be specified. Before a final order for proximity suits is made, a sample should be evaluated.

c. Candidate Materials. Pockets and flaps should be constructed of two or more layers of the same outer shell material as used in the coat or trousers.

13. HANGER LOOP. Hanger loops should be provided for hanging the coat and trousers. The loops should withstand static loads of eighty pounds.

14. LABELING. Labels should be specified, conspicuously placed and display the following information:

a. Manufacturer;

b. Fiber Content of the outer shell material;

c. Size of the garment;

d. Care Instructions including laundering;

e. Use and Assembly Instructions; and

f. Warning "This ensemble must be worn fully assembled to provide proper protection.

15. SIZING. If a garment is too small for the wearer, hot spots will occur on the tight and compressed portions, maneuverability will be restricted, and donning time will increase. The methods of measuring for size vary between manufacturers; the precise method should be known before ordering. The availability of sizes to accommodate a wide range of firefighters should also be determined before selecting a supplier.

16. SERVICE LIFE. Manufacturer's recommended maintenance procedures should be requested when ordering and be followed upon receipt to ensure that the coat and pants provide a cost-effective service life.

a. Usage. Experience indicates that there is improved cost-effectiveness when suits are assigned to individuals and inspections are performed regularly.

Garments tend to be better cared for when identified with an individual than if assigned on a position or shift basis. Thus, improved cost-effectiveness off-sets an otherwise higher initial cost for the larger number of garments.

b. Cleaning. When soiled, the outer shell material loses its reflectivity. Certain fluids, and firefighting agents, if left on the garment after use, reduce reflectivity and accelerate the deterioration of the fabric. Inspections should be frequent, and garments should be cleaned according to the manufacturer's instructions after each use.

c. Storage. When folded and stored in cubicles or on shelves, the reflective outer shell material deteriorates. Coats should be hung on hangers or hooks and trousers hung on hooks to decrease the wear due to folding and abrasion. Store garments in a vented space.

d. Repair. Because of the materials used and the methods necessary, repairs to proximity suit components may rarely be made at airport fire stations. When purchasing, include a requirement that the supplier and/or manufacturer provide a price list for replacing and/or repairing various parts of the coat or trousers, in addition to information on the nature, extent and duration of warranties. Such factors should be considered in choosing a cost-effective garment.

SECTION 3. DETAILS OF PROXIMITY SUIT COAT

17. COLLAR.

a. General. The type of collar specified depends on the type of firefighting strategy used. If the proximity suit coat is used only with the full proximity suit hood, which covers and protects the head and neck, a sophisticated collar design may not be necessary. If, however, the firefighting strategy involves any possibility that the proximity suit coat may be used in conjunction with a structural firefighter's helmet, collar design will be crucial for protection of the neck from exposure to spattering liquids and radiant thermal energy. For operational flexibility, the high collar described below should be specified.

b. Functional Characteristics.

(1) Stiffness. Factors affecting the ability of the collar to stand up and fully cover the exposed neck area include a contoured shape and multiple layers of material or an inner core to provide the necessary stiffness to keep the collar raised.

(2) Shape. When raised, the collar should be contoured to fit the shape of the head. The height of the raised collar may range from three inches at the back of the neck to five and one-half inches at the throat.

(3) Closure. This is an essential safety feature for a proximity suit and should be operable by gloved hands. It is usually a strap, customarily three inches in width and six to eight inches in length.

c. Candidate Materials. The outer surface of the raised collar is should be the same material as used for the outer shell of the coat. The inner surface of the collar, which lies against the neck when raised, can also be made of the same material as the outer shell. However, a softer material, such as PFR cotton corduroy may be used to provide greater comfort. The closure should consists of two layers of outer shell material and should be held closed by Velcro® or a snap. Velcro® allows flexibility in the tightness of the closure and easy attachment with gloved hands. If Velcro® is chosen, it should be able to withstand the effects of temperature, moisture and repeated use. Snaps may be less expensive than Velcro® but are more difficult to attach with gloved hands. In addition, if the snap is metal, any possibility of skin contact with the snap poses a risk of pain or burn from contact.

18. SLEEVES.

a. General. Sleeves should provide protection to the arms while allowing for maneuverability.

b. Functional Characteristics.

(1) Seams. Sleeves may have either one or two seams running from the shoulder to the wrist. Two seams provide a more accurately contoured sleeve design; however, the fabrication cost may be higher than the single seam design.

(2) Attachment to Shoulder. To allow full movement of the arms, a gusset or bellows design for the shoulder should be specified.

(3) Elbow. A patch of one additional layer of outer shell material should be added at the elbow. The size of the patch should be in the range of nine inches long and seven inches wide. Some designs extend the elbow patch from the elbow to the wrist to ensure longer wear along the forearm area.

(4) Cuff. To reduce the effects of wear, due to abrasion in the cuff area, reinforcement should be specified. Common designs include the addition of one or more layers of the outer shell material or the use of leather reinforcing. However, if frequently subjected to high temperatures, leather may shrink and/or deteriorate.

(5) Wrist and Forearm. To ensure protection of the wrist and forearm against high temperatures, liquids, or steam, a wristlet should be specified. The most common and least expensive design is a band of either Nomex® or Kevlar® knit which is sewn to the inner side of the coat cuff and slips over the wrist. A more expensive, yet preferred, wristlet design encloses not only the wrist but part of the hand with openings for the thumb, the three middle fingers and the little finger. This design ensures that when the arm is raised, the wristlet will not slip down the forearm to expose the wrist. These designs also incorporate a "water well," or "sleeve well," which is designed to catch water below the wristlet when the arm is raised. These are usually made of a fire-resistant and waterproof

material, sewn to the inside of the sleeve, extending back three to five inches from the wrist. The design chosen depends on whether gauntlet or wristlet style gloves are used.

19. FRONT CLOSURE.

a. General. The front closure should prevent the penetration of water, heat and steam, and enable the firefighter to quickly don and fasten the coat and should not interfere with mobility. Typical front closures incorporate a mechanical fastening system to physically secure the closure, and one or more storm flaps, behind and/or in front of the fastening system.

b. Functional Characteristics.

(1) Zippers. Zippers, also known as slide fasteners, are reliable and produce a secure closure. However, they are difficult to operate when sitting in a vehicle. Zippers may be more easily operated on the short-style jacket than on the long-style coat, due to the bunching-up of the long coat in the lap area when sitting. Zippers are more expensive than D-Rings.

(2) D-Rings. Hooks and D-Rings are used to secure the front closure as well as to secure an outer storm flap over a zipper. They are reliable, easy to fasten, and low in cost. When used as the principal fastener for securing the front closure, an inside storm flap should be specified. Some designs add a second storm flap on the exterior of the closure to cover the D-Rings. Covering the D-Rings keeps them cooler, which eases gloveless detachment and lessens the opportunity for the fasteners to catch on equipment. When specifying D-Rings, the hooks should face inward. The top hook may face outward for easier manipulation.

(3) Snaps. Snaps can be used to secure storm flaps. Although low in cost, snaps may be difficult to attach with gloved hands.

(4) Velcro®. Velcro® is commonly used to secure both interior and exterior storm flaps. Velcro® is easy to open and close and provides a greater seal than D-Rings or snaps. Velcro® generally costs more than D-Rings or snaps but less than zippers. Common sizes range from one-half to one and one-half inches in width. Velcro® should be specified to withstand high temperatures, remain effective when wet and operate well after repeated use.

(5) Storm Flaps. Storm flaps may range in width from one and one-half inches to eight inches. The material is ordinarily a doubled layer of the outer shell material and may be lined with vapor barrier material.

20. SHOULDER AND BACK YOKE. The use of SCBA accelerates wear in the shoulder and back yoke areas. To ensure durability, a reinforcing patch consisting of one or more layers of the outer shell material should be specified. The patch should extend from shoulder to shoulder across the back and drape four or five inches down from the shoulder in front and five or six inches down from the collar in back.

SECTION 4. DETAILS OF PROXIMITY SUIT TROUSERS

21. SUSPENDERS. Typical suspenders are one and one-half inch wide, heavy-duty elastic employing button attachment and leather trim. Suspenders should be adjustable. Bib-style pants which use the outer shell material for the shoulder straps incorporated into the trouser design, would not need separate suspenders to be specified.

22. LEGS.

a. General. The legs should accept a knee high length firefighter's boot. Some designs incorporate a boot well inside the bottom twelve inches of the trouser legs. With this design, the thermal liner stops at the beginning of the boot well. Because of the insulation capability of the boots, there is no need for additional insulation of the leg around the boot. To lower the possibility of flame licks, or heat going up the trouser leg, an elastic band may be specified at the trouser cuff.

b. Functional Characteristics.

(1) Knees. Knees should be reinforced with an extra layer of outer shell material ranging from eight to ten inches in width and from ten to twelve inches in length. Because of compression in the knee area, the insulation value of the trousers is reduced. Hence, the addition of an extra layer of Nomex needle-punch insulation behind the reinforcement patch is recommended.

(2) Crotch. The crotch area may require a reinforcing patch made of a single layer of outer shell material. Although protection is increased, the added stiffness limits mobility if not carefully tailored.

(3) Cuffs. Trousers cuffs should be reinforced with one or more layers of outer shell material or leather. The reinforcement should cover the circumference of the trousers cuffs, extending one-to-two inches up from the cuff edge on both the inside and outside of the trouser legs.

23. FRONT CLOSURE. The front closure of the trousers should prevent the penetration of water, heat and steam, and allow quick donning and fastening, while not interfering with mobility. Typical front closures incorporate a mechanical fastening system to physically secure the closure and storm flaps behind and/or in front of the fastening system to limit the penetration of heat and liquids. A common design uses a zipper closure and a front storm flap secured with snaps or Velcro®.

CHAPTER 3. HEAD AND FACE PROTECTION

SECTION 1. GENERAL CHARACTERISTICS OF HOOD, HELMET AND VISOR

24. GENERAL REQUIREMENTS. The proximity suit hood assembly, which includes the visor and helmet, should be designed to provide the firefighter with the same level of protection and maneuverability in the same environment as that described in paragraph 4 relating to the proximity suit coat and trousers.

25. DESIGN CRITERIA. The hood assembly should fully cover the head and neck areas and drape over the shoulders. The use of underarm straps to hold the assembly in place is not recommended. Past experience has shown that this design slows donning and limits visibility when turning the head from side to side. SCBA compatibility can be improved by contouring the back of the hood to drape over the SCBA tank. The major design criteria influencing the choice of hood assembly, (hood, helmet and visor) are essentially the same as those for the proximity suit coat and trousers discussed in paragraph 5; i.e., fabric, maneuverability, purchase price, durability and maintainability/repairability.

26. STYLE. The operational requirement of the hood assembly, i.e., protection of the head and face, tends to limit the style to a unit that fits on over the head and is sufficiently long to drape over the shoulders. The principle differences in the function of the components, which could be seen as style differences, is discussed in the sections covering the individual hood assembly components.

SECTION 2. SELECTION OF ASSEMBLY COMPONENTS

27. HOOD. Chapter 2, "Torso and Limb Protection," paragraphs 7 through 10 provide a detailed discussion of the outer shell, vapor barrier, thermal liner, and stitching and seams that also apply to the hood.

28. HELMET.

a. General. A helmet should be specified that can meet the impact and thermal rquirements of a recognized industry standard such as the Model Performance Criteria for Structural Firefighter's Helmets, August 1977, U.S. Fire Administration, OSHA Standard 1910, 156, Subpart L.

b. Functional Characteristics. The helmet should be securely attached to the hood and be able to be detached.

(1) Attachment. Mounting systems which allow the helmet to swivel front and back within the hood are not recommended. Swivel mounting causes the hood to feel loose on the helmet, especially when leaning forward. This sensation causes firefighters to reach up to try to steady the hood. Samples of any proposed attachment method should be evaluated by the user before purchasing.

(2) SCBA Compatibility. To obtain the needed space for a SCBA face mask, some hood assemblies require a change in the mounts to shift the whole hood forward relative to the helmet. The purpose of this change is to increase the space between the visor and the face to allow for a SCBA face mask and to ensure that the visor does not touch the nose. The need for such a post manufacture adaptation should be determined from the evaluation of a model before a final selection is made.

(3) Suspension. The suspension system should provide sufficient strength and clearance to protect the wearer under impact conditions and allow circulation of air between the helmet and the head for ventilation. The use of leather or another absorbent material for the head band may be preferred to plastic.

(4) Sizing. If hood assemblies are to be used by more than one person, the helmet head band size should be quickly and easily adjustable. The most common adjustment mechanism is a knob-type variable adjustment.

(5) Chin Strap. The chin strap should secure the head gear comfortably and allow rapid donning. Many designs use an elastic chin strap which allows for easy doning and minimizes adjustment difficulties.

(6) Nose Guard. Some designs utilize a stiff band of material which is attached securely to the helmet and passes in front of the nose to ensure that the visor, which is integral with the hood, does not touch the nose. The nose guard is intended to eliminate burns on the tips of users noses from contact with the visor. However, it also eliminates the possibility of using a SCBA face mask in conjunction with the hood. Since the SCBA can serve the same purpose and its use is strongly recommended and even required in some jurisdications, the nose guard should not be specified.

c. Candidate Materials. The materials used in the helmet shell, suspension system, and associated straps will depend on the specific standard used by the helmet manufacturer.

29. Visor.

a. Functional Characteristics.

(1) Visibility. The visor should allow relatively clear, undistorted view through an arc as close to 180° as practical construction limits will allow.

(2) Protection. The visor should protect the firefighter from radiant thermal energy, resist abrasion and breakage from impact and be shaped to avoid contact with the nose.

(3) Compatibility with SCBA Face Mask. The visor shape should allow for the use of the SCBA full face mask. The compatibility of the visor with the SCBA face mask in service at the specific airport should be validated before a purchase is made.

(4) Ventilation and Communication. A hinged visor is recommended as it increases ventilation and allows communication without complete removal of the hood. The visor can either swing up or swing to the side. The most common design is the swing-up type. The latch system should be easy to manipulate with gloved hands, be secure so the visor does not open inadvertently, and be sturdy so it will not break after repeated use. A single swivel latch with an aluminum ring tab is recommended.

b. Candidate Materials.

(1) Visor base. Acrylic or polycarbonate is recommended as the base visor material.

(2) Reflective Surface.

(a) A vacuum-deposited, gold coat should be specified on the exterior to reflect radiant energy.

(b) A silver-coated visor which is said to exhibit similar reflective properties as the gold-coated design and have greatly improved wear characteristics is starting to become available. Limited information prevents a recommendation for its use. However, this option should be examined carefully as developments progress.

c. Care and Maintenance. Protection flaps should be provided to cover the visor window when not in use. An alternative is to store the hood assembly in a bag. A visor should be replaced when vision is impaired by scratches on the surface or when the reflective coating has worn thin.

SECTION 3. HOOD, VISOR, AND HELMET ASSEMBLY

30. CARRYING. Carrying the hood by the outer shell tends to wear down the reflective properties of the shell. The addition of a carrying ring or strap tends to lengthen the life of the hood. The design should ensure that the strap does not hang so loosely that it may catch on objects at a fire scene.

31. STORAGE. The hood should be hung by the carrying ring/strap from a hook to reduce abrasion and increase ventilation. A metal loop fixed to the top of the hood may be specified for this purpose. It is cost-effective to select a ring/strap design which fulfills both carrying and storage requirements.

32. STITCHING AND SEAMS. All seams should be double stitched and all stress points should be bar-tacked. The load bearing seams should have a breaking strength of eighty pounds. The thread used should be able to withstand high temperatures while under stress. The thread should be Nomex®, Kevlar®, or equivalent.

33. LABELING. A label should be specified, predominantly displayed and include the following information:

a. Manufacturer;

b. Fiber content of the outer shell material;

c. Care Instructions including laundering; and

d. Date of purchase. (optional)

34. SERVICE LIFE. Manufacturer's recommended maintenance procedures should be followed to ensure that the hood assembly, including visor and helmet, provide cost-effective service.

a. Usage. When assigned on an individual basis, with inspections performed regularly, the hoods tend to be better cared for than if assigned on a position and/or shift basis. Crewmember training in proper handling will also lengthen the life of the reflective surfaces of the visor and the outer shell.

b. Cleaning. When soiled, the outer shell material loses its reflectivity. Certain fluids and dry chemical agents, if left on the hood for an extended period, accelerate the deterioration of the outer shell. Inspections should be frequent, and the hoods should be cleaned according to the manufacturer's instructions after each use.

c. Repair. When purchasing, specify that the manufacturer provide a price list for replacing and/or repairing various parts of the head gear including the visor, especially the reflective coating, and the helmet to hood attachment.

CHAPTER 4. FOOT AND HAND PROTECTION

SECTION 1. SELECTION OF FOOT PROTECTION

35. GENERAL REQUIREMENTS.

a. Boots. Standard structural firefighter's boots should be specified. In cold climates or if slightly more protection from conducted and radiant thermal energy is desired, specify insulated boots. Although good protection is provided by these boots, it is not as great as that provided by the overall proximity suit. With current technology, it is practically impossible to have foot protection which is equal to the general level of protection provided by the suit.

b. Booties. Booties are designed to wear over a boot and consist of leather bottoms with aluminized material uppers. The purpose is to provide greater foot protection from high levels of radiant energy. Although effective in reflecting radiant energy, the booties have been shown to limit the firefighters maneuverability and to have a very short life cycle. The leather soles make walking more difficult. Hence, they are not recommended.

c. Trouser Cuff Extensions. A more acceptable method used to protect the upper portion of the foot below the trouser cuff incorporates a flared trouser cuff extension in the shape of a spat; this extends from the cuff over the upper portion of the foot. It should be small enough to eliminate the possibility of catching on objects on the ground or to hinder ladder operations. The cuff extension provides greater protection than the boot alone, while ensuring maneuverability. The material used should be the same as the outer shell material of the trousers.

36. FUNCTIONAL CHARACTERISTICS. Boots should be knee high, compatible with trousers design, and easy to don. Straps should be specified at the top of the boot to assist in rapid donning.

37. CANDIDATE MATERIALS.

a. Soles and Uppers. Boot uppers should be constructed of polyurethane-coated rubber. Other available materials include leather and aluminized rayon, although these are not recommended. Soles should also be composed of rubber and should be designed to maximize traction under adverse weather and soil conditions.

b. Midsole and Shank. Midsoles and shanks should be constructed of steel to provide support and puncture protection for the instep and sole of the foot.

c. Toe Box. Protection for the toes should be provided by a steel toe box which meets American National Standards Institute (ANSI) standards.

d. Linings and Insoles. A variety of fabrics are acceptable to line the interior of the boot, including wool, felt, rubber, neoprene, foam, cotton and nylon. Linings should be selected to provide insulation, protect shins, enhance comfort, and provide long service life.

SECTION 2. SELECTION OF HAND PROTECTION

38. GENERAL REQUIREMENTS. Hand protection should be designed to protect the firefighter's hands from conducted and radiant thermal energy, be durable, resist puncture, cutting and tearing, and allow sufficient manual dexterity to enable manipulation of tools and machinery.

a. Mittens vs. Gloves. Glove styles should be specified over mitten styles because of the increased dexterity provided. New materials have made possible glove designs which provide levels of protection equivalent to those of older mitten styles.

b. Wristlets vs. Gauntlets. Although the wristlet design is lighter and allows greater maneuverability, it does not provide the reflective protection in the wrist area which the gauntlet design provides. In choosing between the two styles, the design of the coat sleeve should be considered. For operational flexibility, firefighters should carry two pairs of gloves: one an aluminized gauntlet style, and the other nonaluminized with a wristlet. This enables the firefighters to choose between protection and maneuverability as required by the task at hand.

39. FUNCTIONAL CHARACTERISTICS.

a. Conductive and Radiant Thermal Energy. Hands should be protected from high temperature objects and high levels of radiant thermal energy. Thermal protection should be sufficient even when the layers are compressed due to gripping objects. Material should be heat and flame resistant.

b. Puncture and Cut Resistance. Hand injuries account for a large portion of firefighting injuries. Therefore, material selected to protect the hands should be resistant to puncture, cutting, and tearing. (See Chapter 2, Section 2, paragraph 7.c for discussion of materials).

c. Dexterity and Gripping. A firefighter should be able to perform all tasks requiring manual dexterity at the fire scene. This criteria runs counter to the conducted and radiant thermal energy protection criteria which generally require a thickness that limits dexterity. Thus, a compromise is required between dexterity and thermal protection.

d. Wrist and Forearm Protection. The wrist area should be effectively covered by either overlapping the coat sleeve with a gauntlet or incorporating a wristlet which covers the wrist and lower forearm. There should be continuous coverage between the sleeve and the hand even when the arms are raised.

40. CANDIDATE MATERIALS.

a. Outer Shell. Kevlar®, Nomex®, PBI, and PFR rayon are recommended materials for the outer shell.

b. Palm. Leather is very often used on the palm of the glove.

c. Vapor Barriers. Neoprene is recommended for the vapor barrier.

d. Thermal Liners. PFR cotton, PFR wool, Kevlar®, or Nomex® should be specified for the thermal liner. Often there is an option for removable or nonremovable inner liners. Removable liners are preferred when increased dexterity is required, as in handling aircraft switches, i.e., the outer glove can be removed, leaving the protective inner liners.

e. Wristlets. Kelvar®, Nomex®, or Kynol® is recommended because of generally high puncture resistance and good thermal characteristics.

CHAPTER 5. COMPATIBILITY WITH SELF-CONTAINED BREATHING APPARATUS (SCBA)

1. GENERAL. When specifying proximity suits it is very important to emphasize he need for compatibility of the garments selected with the specific SCBA in use.

a. Coat. The use of a pouch to enclose the SCBA air tank is not recommended. owever, wear in the shoulder and back yoke areas of the coat from the use of SCBA houlder straps can be reduced by specifying one or more added layers of outer hell material on the shoulder and back yoke areas to protect against this addi- ional wear.

b. Hood. When purchasing protective head gear, a hood should be chosen which s compatible with the SCBA harness and tank system in use. The hood should be esigned to closely drape over the top of the tank or fit neatly between the coat ack and the top of the tank.

c. Visor. The visor of the protective head gear should allow sufficient learance from the face to permit the use of a SCBA face mask. Compatibility is etermined by the size and curvature of the visor and position of the hood on the elmet.

d. Nose Guard. The nose guard has been shown to be incompatible with the use f some SCBA face masks. If the nose guard is eliminated, protection to the nose ust be provided when a SCBA is not in use. This can be accomplished by specifying design which increases the space between the visor and the nose by moving the ood assembly forward relative to the helmet, or specifying an alternate visor hape.

e. Pockets. The straps which attach the SCBA to the firefighter's back hould not interfere with the ability to use the pockets. Compatibility with ctual in-service SCBA should be verified before pocket locations are specified.

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